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New Millennium Program
Space Technology 7
Technology Announcement

Aeroentry/Capture/Maneuver Technology

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Introduction

- Aerocapture is a flight maneuver performed by a spacecraft to get into orbit at a planet using only 1 atmospheric pass
  - atmospheric drag decelerates the vehicle to change the trajectory from a hyperbola to an ellipse (i.e., ”capture”)
  - it is <u>not</u> the same as aerobraking in which atmospheric drag is used to lower the apoapsis of an existing elliptical orbit
  - after aerocapture, the spacecraft needs to execute a small propulsive maneuver at apoapsis to raise the orbit out of the atmosphere
  - <u>Aerocapture has never been done before</u>

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Benefits of Aerocapture

- Aerocapture can save significant amounts of mass compared to the usual propulsive orbit insertion
  - it is a trade between lots of propellant saved vs the required mass of the aerocapture system itself
  - these mass savings can translate into either smaller launch vehicles or increased payload
- Several future NASA planetary missions are either enabled or greatly enhanced by aerocapture technology:
  - Mars Sample Return, Titan Explorer, Neptune Orbiter, Venus Surface Sample Return

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Flight Test Rationale

- Aerocapture flight speeds cannot be duplicated in wind tunnel facilities. Therefore,
  - there is a need for flight test data on the critical aspects of flow field structure, active guidance performance, aerodynamic forces and aerothermo-chemistry
  - flight data is needed to validate the computer models that must be used to design flight vehicles
- Since aerocapture has never been done before, a flight test is a necessary risk reduction exercise prior to a major planetary science mission

Baseline Technical Approach

- The baseline approach is to use a maneuverable blunt-body aeroshell for the ST-7 aerocapture flight test
  - it is the most mature concept based on a long R&D history of adopting blunt body entry capsule technology to aerocapture
  - the aeroshell serves the dual functions of providing the required aerodynamics and protecting the internal spacecraft
- The ST-7 cost cap may preclude the propulsion system needed to put the test vehicle on an inbound hyperbolic trajectory at Earth
  - therefore, the team adopted the working premise that a high elliptical orbit with an atmospheric entry speed of >10 km/s and a velocity decrease of >2.2 km/s during atmospheric flight would be sufficient for demonstrating aerocapture

Baseline Flight Experiment Sequence

- Launch into orbit
- In space propulsion and navigation to achieve the desired inbound trajectory
- Hypersonic flight through the atmosphere
  - maneuver the vehicle with onboard active guidance and reaction control system
  - minimum altitude will be ~75 km
  - achieve post-aerocapture orbit with apoapsis of ~300 km.
  - transmit some amount of engineering data
- Vehicle coast to apoapsis. Start of data playback
- Propulsive maneuver at apoapsis to raise orbit out of the atmosphere
- In orbit for 1 or more revs to complete playback of engineering data
- De-orbit burn to bring the vehicle back to Earth

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ST-7 Aerocapture Technology Premise

- "It must be emphasized that the key to aerocapture is a successful systems level integration of the various technology elements into a robust flight vehicle. Therefore, the ST7 Concept Definition Study Phase ("Study Phase") is expected to focus on the key systems engineering and low-cost flight test problems that must be solved to produce a flight validation experiment and flight vehicle design that maximizes the chances of success with a high data return on the engineering performance of the aerocapture system."
  - we are not looking to optimize individual technology elements at the expense of the overall systems solution
  - reliability is essential to ensure success

Aerocapture Solicited Technologies

- The ST-7 Aerocapture team is soliciting the following 4 technologies:
  - Aeroshell Design and Fabrication
    - 1 opportunity @ $50K
  - Aerodynamic and Aerothermodynamic Design
    - 1 opportunity @ $50K
  - Aerocapture Guidance Algorithm
    - 1 opportunity @ $50K
  - Advanced Instrumentation
    - 1-3 opportunities @ $50K each

Aeroshell Design and Fabrication

- This element concerns the thermo-mechanical design of the aeroshell
  - a basic structure sized for launch and aerodynamic loads
  - thermal protection material on external surfaces to protect the internal spacecraft from heating
- "Proposers should submit a candidate aeroshell mechanical design with the following approximate characteristics that will be used as the starting point for the Study Phase:"

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Aeroshell Design and Fabrication (cont.)

(1) Blunt body shape similar to Viking-style 70° sphere cones or Huygens-style 60° sphere cones.

(2) The largest diameter that can be afforded within the ST7 project, but not to be less than 1 m in diameter. It is highly desirable that the mechanical design be scalable to the 3 to 4 meter diameter sizes expected in future NASA aerocapture missions.

(3) Hypersonic lift-to-drag ratio of at least 0.2, with higher values preferred.

(4) Ballistic coefficient in the range of 80 to 120 kg/m^2.

(5) Minimum inertial entry velocity of 10 km/s.

(6) Partial backshell or suitable feedthroughs to enable spacecraft telecom, navigation, reaction control system and thermal management functionality. This functionality is preferred to concepts involving external carrier spacecraft that must be jettisoned prior to aerocapture.

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Aerodynamic and Aerothermodynamic Design

- This element concerns the aerodynamic and aerothermodynamic design of the aeroshell
  - aerodynamic performance sufficient to deliver the vehicle into the desired aerocapture orbit
  - pressure and heating data needed to do the thermo-mechanical design of the aeroshell
- “Proposers should submit a candidate aeroshell aerodynamic design with the following approximate characteristics that will be used as the starting point for the Study Phase:”

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Aerodynamic and Aerothermodynamic Design (cont.)

(1) Nominal blunt-body aeroshell size of 1 m diameter, or greater

(2) Hypersonic lift-to-drag ratio of at least 0.2, with higher values preferred.

(3) Ballistic coefficient in the range of 80 to 120 kg/m^2.

(4) Minimum inertial entry velocity of 10 km/s.

(5) Consistency with the mission sequence outlined in Section 2.0 above.

"It is expected that proposers will justify their designs with real gas, 3-D computational fluid dynamics simulations and 6 degree-of-freedom trajectory analyses. Designs that are shown to be applicable to future Mars, Titan and Neptune aerocapture missions will be preferred."

Aerocapture Guidance Algorithm

- This element concerns the guidance algorithm needed to actively control the vehicle during aerocapture
  - "The guidance will be designed to control the ST7 test vehicle from atmospheric entry interface to the desired exit apoapsis and exit inclination using bank angle control only."
  - guidance is for a blunt body shape as described in the previous two technology elements (aeroshell aerodynamic and mechanical design)
  - additional technical details provided in section 3.2c of the solicitation
- Proposers must include computer simulation results that demonstrate the performance of their guidance algorithm for this application.

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Advanced Instrumentation

- This element concerns advanced flight instrumentation that can provide important vehicle and flow field data during the ST-7 flight
  - "It is expected that the flight instrumentation will be a mixture of proven, off-the-shelf devices to guarantee a minimum data return on the vehicle dynamics and temperature response, and advanced devices that offer either substantial mass, power or accuracy improvements over proven devices, or can provide additional, but difficult to obtain, information on the surrounding flow field."
  - This solicitation refers only to potential new instrumentation
- "Proposers should submit design and performance estimates for candidate new technology engineering sensors that are applicable to the ST-7 flight measurement needs in the following areas:"

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Advanced Instrumentation (cont.)

- A data collection system for surface pressure measurements at multiple locations
  - on both the fore and aft shell
  - want to be able to determine angles of attack and sideslip
  - pressure range of 1 - 2000 Pa, sampling rate of ~1 Hz
  - desirable to be less massive than 100s of grams typical of existing diaphragm pressure transducers
- Local heat flux sensors
  - want to get heat fluxes to the aeroshell surface at multiple locations
  - 5 to 300 W/cm2 on forebody, 1 to 20 W/cm2 on aft body
  - sampling at ~1 Hz

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Advanced Instrumentation (cont.)

- Sensors for the bow shock heated gas flowing around the vehicle
  - can be remote (photometry or spectorscopy) or direct sampling of gas to internal instruments
  - concepts that can operate in the presence of heat shield ablation products are especially desired (may or may not be necessary)
  - particularly interested in gas species like N_2+, O_2+, N and O that have relatively large uncertainties in computer themochemical models
  - desirable that composition instruments be adaptable to the CO_2 and H_2 atmospheres of other planets
- The Concept Study will determine which of the advanced instrumentation concepts can be included in the flight vehicle given the engineering and cost constraints on the ST-7 mission